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Abundance Estimation of *Illex illecebrosus* During the Joint Canada-Japan Selectivity Research Program on the Scotian Shelf in 1978

by

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INTRODUCTION

Data for this report were collected during the joint Canada/Japan 1978 mesh selection research program. Two cruises were carried out on the Japanese commercial stern trawler, Shirane Maru, from June 3 to July 3, 1978 (Cruise 1) and from October 17 to November 16, 1978 (Cruise 2). Each cruise was divided into two legs of approximately fifteen days duration. The purpose of the cruises was to conduct a mesh selectivity study and to determine the biology and distribution. The random nature of the sampling permitted the present estimation of abundance of Illex illecebrosus.

The four stations defined for the cruises were 1) Emerald Basin, 2) Sable Island Bank, 3) Banquereau Bank, and 4) Emerald Bank (Figure 1). The survey stations were determined by virtue of the high squid landings in 1977 in those areas. In abundance surveys, concentrated sampling in areas of high fish density is preferable to spreading sampling effort evenly throughout a very large area (Saville, 1977). Although there is distinct seasonality in the distribution and abundance of squid, their summer offshore presence is evident throughout the sampling areas (Waldron, 1978). The significant year-to-year changes in abundance (Amaratunga et al., 1978) dictates that this type of survey be carried out over several years.

This survey attempted to minimize random and systematic errors usually encountered in population surveys. Random errors due to variances between individual hauls result in low precision. An attempt was made to maximize precision by increasing the number of hauls and also by stratifying sampling. Systematic error due to biases which affect accuracy result from such factors as use of wrong gear, mesh selectivity, diurnal changes (Saville, 1977). These factors were intrinsically checked in the survey.

The areal expansion method has been commonly used in assessing stock size (eg., Scott, 1976; Ikeda et al., 1973). Sissenwine (1976) critically reviewed this and other assessment methods, and many drawbacks were pointed out. Recognizing these limitations and that under-estimation of catch per unit area (Ikeda et al., 1973) is likely, the present study used this direct (areal) method to obtain indications of abundance and relate them to distribution aspects of Illex. The data also provided an insight to gear performance.

METHOD

In Cruise 1, 110 sets were made in each leg, within the four stations, using a standard bottom trawl equipped with covered codends (Amaratunga et al., 1979). Of these, only 108 sets per leg were applicable to this study (see below). Three codend mesh sizes of 45 mm, 60 mm, and 90 mm with corresponding covers of 20 mm, 35 mm, and 40 mm were used, one codend per day, at each station. Sampling was depth stratified and the locations were randomly placed on suitable contours at depths ranging from 50 m to 300 m. Sets were one-half hour long and were conducted throughout the day. An average of nine sets were done per 24-hour period (day). The physical data collected for each set included date, gear type (defined by codend mesh size) and starting and finishing depth, time of day, location, and surface and bottom temperature. Catch weight (kg) for codend and cover were recorded by species.

Cruise 2 occupied only the latter three stations, with minor alterations to the coordinates in order to accommodate deep-water sets (Figure 2). In Legs 1 and 2, 85 and 90 sets were made, respectively. Of these, only 78 and 75 sets of Legs 1 and 2, respectively, were used in the abundance estimations as several of the trawls were invalidated due to torn nets and "search and fish" techniques which were non random. The sets were one hour long (except for the first set in Leg 1 which was one-half hour), and an average of seven sets were done in a day. Sampling was depth stratified at suitable contours ranging from 100 m to 1000 m. Set data were the same as those taken on Cruise 1; however, different codend mesh sizes were used. In Leg 1, codend mesh sizes of 60 mm, 90 mm, and 130 mm had covers of 35 mm, 40 mm, and 60 mm, respectively. In Leg 2, codend mesh sizes of 90 mm, 100 mm, and 130 mm had covers of 40 mm, 60 mm, and 75 mm, respectively.

The biomass estimates were calculated from squid catch weights by the areal expansion method.

The catch per unit area of Illex, Ca, was calculated as follows:

$$Ca = Co/K \text{ (kg/hectare)}$$

where: Co is the catch per tow (kg), and K is the area swept by the trawl (hectares), calculated by:

$$K = \frac{D \times 1853 \times L}{10000}$$

where: D is the distance between trawl doors (m), 1853 is the number of meters in a nautical mile, L is the distance travelled by the trawl in each tow (nautical miles), and 10000 is the number of square meters in a hectare.

The stock abundance, BIO, was calculated by:

$$BIO = H \times Ca/q$$

where: H is the area of each station (hectares), and q is the catchability coefficient.

The distance travelled by the trawl (L) was calculated from the starting and finishing latitudes and longitudes as the boat speed for each tow was not recorded.

The catch per unit area of Illex was determined in this manner for each tow, and an average catch per area was calculated for each station and analysed in relation to mesh size, time, and depth.

RESULTS

Catch data summarized in Table 1 show true averages of squid catches in relation to other fish. The summary which incorporates data from all sets show squid were encountered in most sets. The averages in Cruise 1 usually ranged less than 50 kg per one-half hour tow. In Station 1 of Leg 1, there were two unusually large squid catches which resulted in the apparent high average for that station. By-catch in Cruise 1 was very high. The averages in Leg 1 of Cruise 2 ranged close to 200 kg per one hour tow. Much higher averages observed in Leg 2 were a result of "search and fish" methods (commercial methods) employed on one set each day.

The biomass estimates (Table 2) were made utilizing only data from valid sets. Observed catch per unit area (CA) during Cruise 1 (June) was significantly lower than in Cruise 2 (October/November). Similarly, CA in both cruises progressively increased during the time lapse from Leg 1 to Leg 2. While biomass progressively increased with time, numbers of squid remained relatively uniform through Cruise 1 and Leg 1 of Cruise 2. There was a significant increase in numbers in Cruise 2, Leg 2.

Station 2, Sable Island Bank, consistently had relatively high CA values. This was most apparent in Cruise 2 when largest biomass values were recorded in this station in both Legs 1 and 2. In Cruise 1, Leg 1, the largest biomass was recorded in Station 1. Two sets with large catches in this station resulted in this upward bias. In the absence of these two anomalies, the catch per hectare decreased from 2.591 (Table 2) to 0.083 with a biomass estimation at q = 1 of 50.4 MT. If these anomalies were taken into consideration, Cruise 1 would consistently have recorded the largest biomass in Station 4, Emerald Bank.

Table 3 summarizes data stratified by codend mesh size. Average catch per unit area were tabulated by station for each leg. It is important to note here that gear type referred to as 001 or 45 mm, 002 or 60 mm, etc. identify only the codend mesh size and make no reference to the cover mesh size. Since the covers presumably retain escapees from the codends (Amaratunga et al., 1979), it is the cover mesh size that is applicable to this study. However, codend mesh sizes are used here for convenience, especially in relation to the mesh selection study of this program. All calculations during this study took the total combined weights of codend and cover.

Table 3 and Figure 3 show the 90 mm gear type consistently had highest mean catch per unit area although the pattern was not as consistent at each station. The smaller mesh sizes apparently decreased the fishing efficiency. The larger mesh sizes were used only in Cruise 2 when the squid were large (Amaratunga and Roberge, 1979) and squid behavior influences catchability (Amaratunga et al., 1979).

The depth stratified sampling strategy of this program was altered during the program. Cruise 1, Leg 1 carried out sampling by alternating at depths close to 150 mm and 250 m. Subsequent legs attempted to fish at depth contours of 50-100 m intervals. During Cruise 1, the maximum depths attempted were close to 300 m, while in Cruise 2, attempts were made to go down to 1000 m. The minimum depth sampled was 73 m.

Catch per unit area at various depths were cross-tabulated by station and by leg (Table 4). Cruise 1 data are presented in two sets of depth regimes in order to accommodate Cruise 1, Leg 1 strategy. In Cruise 1, CA values were greatest between 50-150 m, while in Cruise 2 the values were greatest at 150-250 m. During Cruise 2, a second mode was apparent between 350-450 m in Leg 1 and between 450-550 m in Leg 2 (Figure 4a and b). Preliminary field observations indicated these deeper water squid were larger and more mature.

Table 5 and Figure 5 show largest catches per area were made during daylight hours. The period between 06:00 hr and 12:00 showed largest CA values in Cruise 1, Leg 2, and Cruise 2, while 12:00 hr to 18:00 hr was best in Cruise 1, Leg 1.

DISCUSSION

This procedure of estimating abundance gives only approximations to the true conditions. The constant q, referred to as catchability coefficient, is difficult to estimate. However, a range of q = 1.0 to q = 0.5 (Table 2) was used to represent the amalgam of many factors that come into play. The preliminary difficulty is estimating the proportion of the stock which becomes available to the gear. When determining area swept by the gear, the stock is assumed to be uniformly distributed over the area (Gulland, 1969); but the evidence is that squid distribution (seasonally and geographically) is patchy (Summers, 1969). This was also apparent from a few unusually large squid catches landed during this program. The present study also showed a diurnal component to their distribution, when the bottom trawl consistently showed larger CA values during the daylight hours.

Saville (1977) points out that a proportion of the population is not available to the trawl beyond the head rope and foot rope. Similarly, the volume actually swept by the trawl will not capture all squid. Amaratunga et al. (1979) showed avoidance behavior of squid. The calculation of area swept by the trawl is more critical. The opening of the trawl mark, D, used to calculate area swept was set at 110 m; the estimated distance between the trawl doors. This value takes into consideration the herding effect of the doors. Herding, however, is not 100% efficient. In addition, the distance between the doors is not constant, and is affected by factors such as vessel speed. Thus, there are intrinsic inaccuracies in estimating K (Mesnil, 1977), and hence, biomass.

The absolute biomass values reported in this paper must therefore be considered as estimations. These estimations, in fact, are liable to vary considerably with time, location, gear, etc. (Saville, 1977). The biomass estimations in Table 1, therefore, essentially relate to the specific areas and the time period under consideration. The critical aspect of this study relates to the relative abundance of stock within the parameters studied.

There were very few recordings of squid catches prior to June, 1978 (Amaratunga and Roberge, 1979). When the survey began on June 3, very small biomass recordings were made in Station 1 (Table 2). These increased from 9.7 MT (at q = 1) to 50.4 MT in approximately two weeks. A further increase was evident in the next few days (first three days of Leg 2). Similarly, biomass estimation in Stations 2, 3, and 4 in Cruise 1, Leg 1, showed increments in Leg 2. This indicated an apparent immigration of squid to the sample areas (Amaratunga et al., 1979). This may then be considered as the recruitment phase of the 1978 stock. In order to clarify the probable immigration pattern from observations on biomass estimations, it was necessary to determine the numbers of animals each biomass estimation represented (Table 2). The numbers also showed increases with time during Cruise 1.

The general distributional patterns indicated squid concentrations in the Emerald Bank and Sable Island Bank during Cruise 1, with the Emerald Bank area showing greater abundance. Two apparent trends noted were: (i) The Emerald Basin station, which is closer inshore, showed increased abundance as Cruise 1 progressed. This may relate to an early summer immigration of squid to the coastline shallow waters (squid were encountered inshore in Nova Scotia early in July). (ii) Late Season (Cruise 2) estimations indicated significant increases in Sable Island Bank area, while the Emerald Bank area showed decreases.

The areal expansion method used for these abundance estimation was demonstrated earlier to have many limitations. Therefore, the biomass calculations can be applied only to the areas sampled. The arbitrary boundaries drawn for each station may in fact be considered as the areas these estimations are valid for. Although the total sampled area (total area covered by all hauls) represented only about 0.2% of the area of the stations, sampling was distributed over much of each station. Thus, these estimations cannot be extrapolated into areas outside of the sample areas.

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TABLE 1. **Summary of *Illex* catches by station from the *Shirane Maru* cruise for the periods June 3 to July 3, 1978, and October 17 to November 16, 1978.** (This table includes all sets for Cruise 1 and Cruise 2.)

Cruise:leg	Date	Station	No. of tows	No. of tows with squid	Avg. squid catch (kg)	Largest squid catch (kg)	Avg. total catch (kg)
1:1	03/06/78	1*	10	8	0.7	2.0	308.6
	to	2	28	27	40.9	545.8	239.8
	18/06/78	3	28	27	14.6	124.8	536.0
		4	27	27	34.7	450.0	260.5
		1*	17	12	132.2	1320.2	1267.6
1:2	19/06/78	1	29	18	23.7	246.2	966.7
	to	2	27	25	51.3	352.9	194.7
	03/07/78	3	27	25	23.3	154.3	800.7
		4	27	26	220.0	1576.3	430.9
2:1	17/10/78	2	28	26	215.5	2932.7	317.4
	to	3	34	30	201.1	1982.8	621.5
	01/11/78	4	23	23	192.0	1479.0	332.2
2:2	02/11/78	2	32	32	715.5	4518.7	823.2
	to	3	30	27	555.5	4572.6	1139.3
	16/11/78	4	28	28	386.0	3887.4	483.6

*Station 1: Day 1, 10 sets were made using 45 mm codend with very poor squid catches. The vessel then moved to Station 2, 3, and 4 before returning to Station 1 to complete one day with 60 mm and one day with 90 mm codends.

TABLE 2. **Biomass estimations by station from the Shirane Maru cruise for the periods June 3 to July 3, 1978, and October 17 to November 16, 1978, using areal** expansion method.

Cruise: leg	Date	Station	No. of tows	Density CA (kg/he)	Area H (he x 10^6)	BIO 1 (M.T.) q = 1	BIO 2 (M.T.) q = 0.5	Numbers 1 (x 10^6) q = 1.	Numbers 2 (x 10^6) q = 0.5
1:1	03/06/78	1*	10	0.016	0.61	9.7	19.4	0.15	0.30
	to	2	28	0.690	0.92	634.8	1269.6	9.78	19.56
	18/06/78	3	27	0.224	0.92	206.2	412.4	3.18	6.35
		4	27	0.624	1.23	767.5	1535.0	10.08	20.15
		1*	16	2.591	0.61	1580.2	3160.4	20.75	41.49
1:2	19/06/78	1	29	0.505	0.61	308.0	616.0	3.94	7.89
	to	2	27	0.898	0.92	826.1	1652.2	10.71	21.41
	03/07/78	3	27	0.397	0.92	356.4	712.8	4.62	9.24
		4	27	4.139	1.23	5091.1	10182.2	65.98	131.96
2:1	17/10/78	2	25	2.350	1.23	2890.1	5780.2	10.36	20.72
	to	3	33	2.083	1.23	2561.6	5123.2	9.18	18.36
	01/11/78	4	20	0.482	2.16	1040.3	2080.6	4.06	8.12
2:2	02/11/78	2	27	5.907	1.23	7265.2	14530.4	25.09	50.18
	to	3	24	4.080	1.23	5018.4	10036.8	16.69	33.38
	16/11/78	4	24	2.141	2.16	4624.0	9248.0	15.10	30.19

*Station 1: Day 1, 10 sets were made using 45 mm codend with very poor squid catches. The vessel then moved to Station 2, 3, and 4 before returning to Station 1 to complete 1 day with 60 mm and 1 day with 90 mm codends.

TABLE 3. Catch per unit area, stratified by mesh size (gear type).

Gear type	Cruise 1									
	Leg 1					Leg 2				
	Sta. 1	Sta. 2	Sta. 3	Sta. 4	$\overline{X}$	Sta. 1	Sta. 2	Sta. 3	Sta. 4	$\overline{X}$
45 mm 001	0.016	0.636	0.097	1.047	0.449	0.668	0.682	0.277	2.458	1.021
60 mm 002	0.047	0.278	0.294	0.576	0.299	0.774	0.531	0.356	3.222	1.221
90 mm 003	5.134	1.001	0.281	0.249	1.666	0.024	1.481	0.558	6.738	2.200
100 mm 005										

Gear type	Cruise 2							
	Leg 1				Leg 2			
	Sta. 2	Sta. 3	Sta. 4	$\overline{X}$	Sta. 2	Sta. 3	Sta. 4	$\overline{X}$
45 mm 001								
60 mm 002	0.375	3.528	0.229	1.377				
90 mm 003	4.207	2.621	0.487	2.438	7.354	12.836	1.045	7.078
100 mm 005					3.510	4.161	6.528	4.733
130 mm 004	0.227	0.766	0.689	0.561	8.361	1.232	0.101	3.231

Table 4. Catch per unit area stratified by depth for each station on Cruises 1 and 2.

Cruise 1											
Depth	Leg 1						Leg 2				
	Sta.1*	Sta. 2	Sta. 3	Sta. 4	Sta. 1*	$\bar{X}$	Sta. 1	Sta. 2	Sta. 3	Sta. 4	$\bar{X}$
50-100	-	-	-	-	-	-	-	1.488	0.285	-	0.887
101-200	0.014	1.184	0.289	0.966	4.539	1.398	0.687	0.895	0.343	4.382	1.577
201-300+	0.020	0.120	0.143	0.196	0.086	0.113	0.027	0.320	0.593	2.197	0.784
50-150	0.012	1.693	0,268	0.971	9.728	2.534	1.001	1.307	0.169	6.129	2.152
151-200	0.022	0.421	0.347	0.946	1.944	0.736	0.342	0.543	0.568	2.635	1.022
201-250	0.020	0.141	0.114	0.188	0.115	0.116	0.031	0.320	0.593	2.197	0.785
251-300+	-	0.073	0.201	0.291	0.012	0.144	0.002	-	-	-	0.002

* See note, Table 1.

Cruise 2								
Depth	Leg 1				Leg 2			
	Sta. 2	Sta. 3	Sta. 4	$\bar{X}$	Sta. 1	Sta. 2	Sta. 3	$\bar{X}$
50-150	0.083	0.062	0.286	0.144	0.967	0.039	2.516	1.174
151-250	6.192	5.257	0.696	4.048	14.871	12.292	4.077	10.413
251-350	1.199	0.377	0.099	0.558	7.629	5.254	1.083	4.655
351-450	0.071	0.210	1.537	0.606	0.090	0.132	0.251	0.158
451-550	0.137	0.490	0.737	0.455	0.258	-	2.609	1.434
550-750	0.049	0.360	0.291	0.233	-	-	0.475	0.475
741-1000+	-	0.168	0.099	0.134	-	-	0.040	0.040

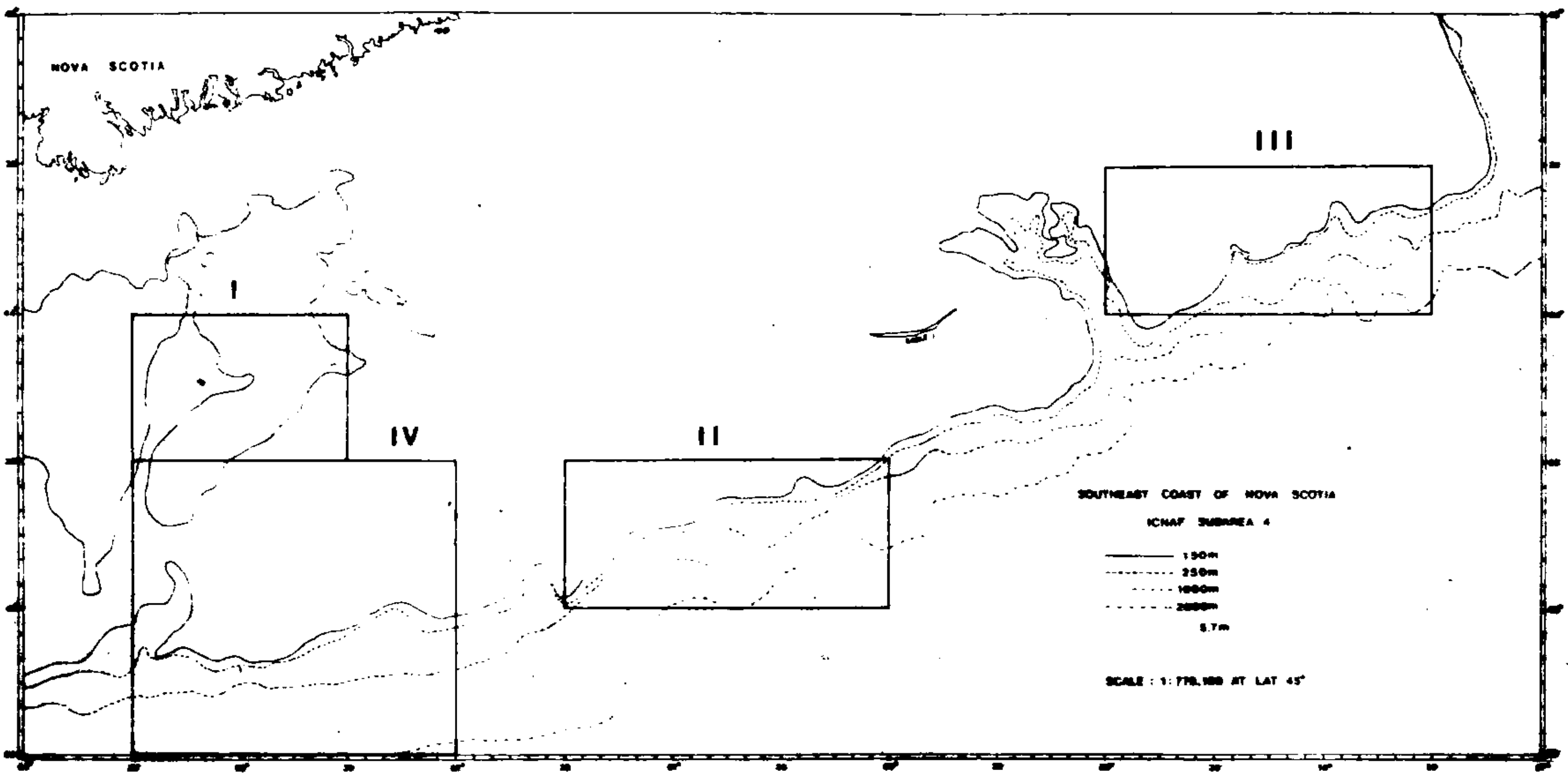
TABLE 5. Catch per unit area stratified by time for each station.

Cruise 1											
Time	Leg 1						Leg. 2				
	Sta. 1*	Sta. 2	Sta. 3	Sta. 4	Sta. 1*	$\bar{X}$	Sta. 1	Sta. 2	Sta. 3	Sta. 4	$\bar{X}$
0000-0600	0.023	0.207	0.403	0.182	0.002	0.164	0.005	0.587	0.262	1.334	0.547
0601-1200	0.002	0.218	0.286	1.324	2.912	0.948	0.514	1.751	0.085	12.521	3.718
1201-1800	0.029	1.696	0.214	0.367	9.740	2.409	0.646	1.118	0.930	1.526	1.055
1801-2400	0.018	0.215	0.044	0.433	0.114	0.165	0.701	0.390	0.349	2.578	1.005

*See note, Table 1

Cruise 2								
Time	Leg 1				Leg 2			
	Sta. 2	Sta. 3	Sta. 4	$\bar{X}$	Sta. 2	Sta. 3	Sta. 4	$\bar{X}$
0000-0600	0.073	0.279	0.097	0.150	4.032	1.546	0.131	1.903
0601-1200	0.777	5.107	0.862	2.249	10.343	3.425	5.519	6.424
1201-1800	3.400	1.229	0.638	1.756	8.318	4.550	0.293	4.387
1801-2400	4.856	0.200	0.221	1.759	0.481	5.976	2.072	2.843

Figure 1. Map showing the four stations occupied during Cruise 1 of the selectivity study on the Shirane Maru, 1978.



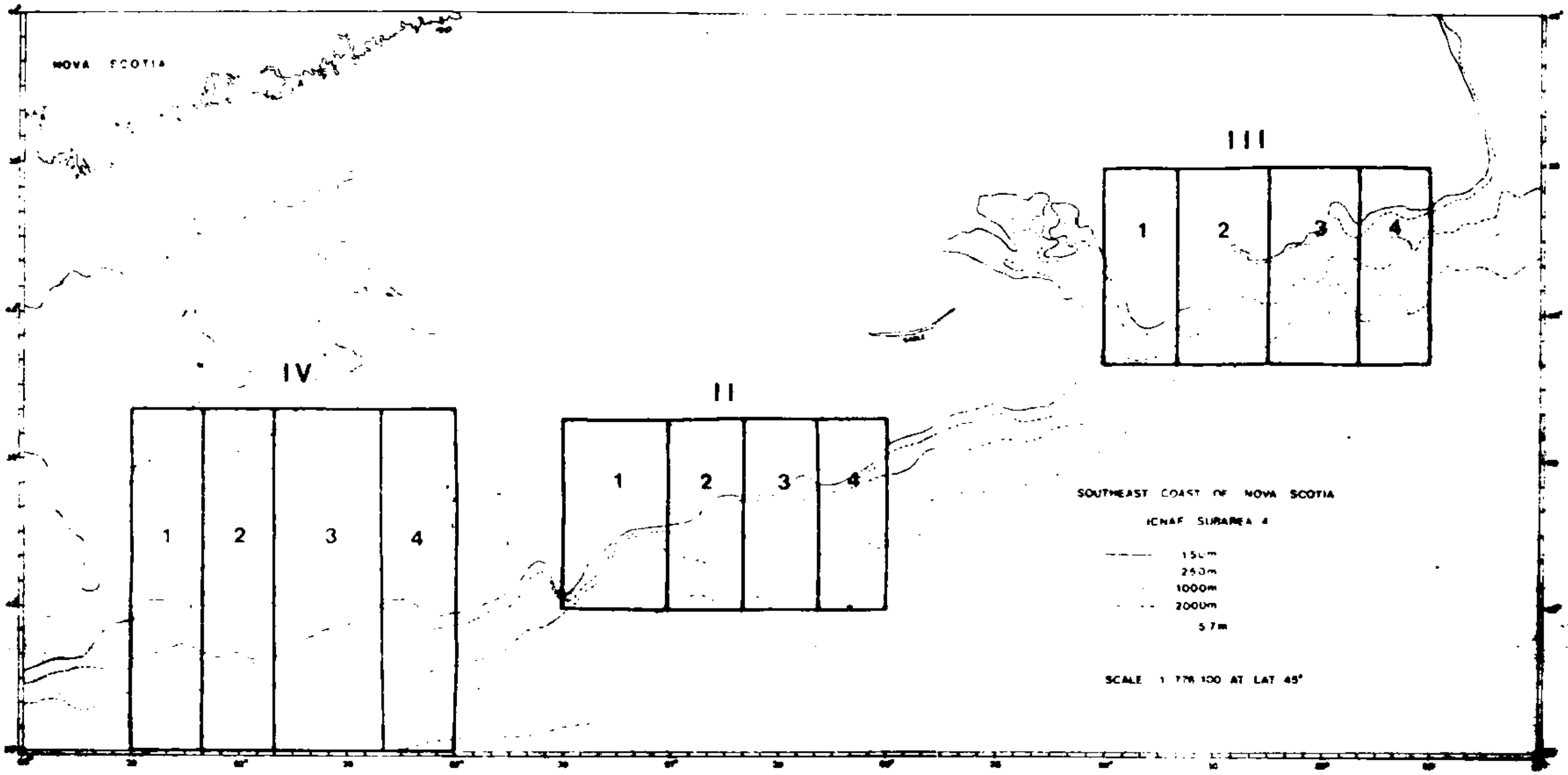
I - Emerald Basin

II - Sable Island Bank

III - Banquereau Bank

IV - Emerald Bank

Figure 2. Map showing the three stations occupied during Cruise 2 of the selectivity study on the Shirane Maru, 1978.



II - Sable Island Bank
III - Banquereau Bank
IV - Emerald Bank

The numbered boxes represent transect within stations.

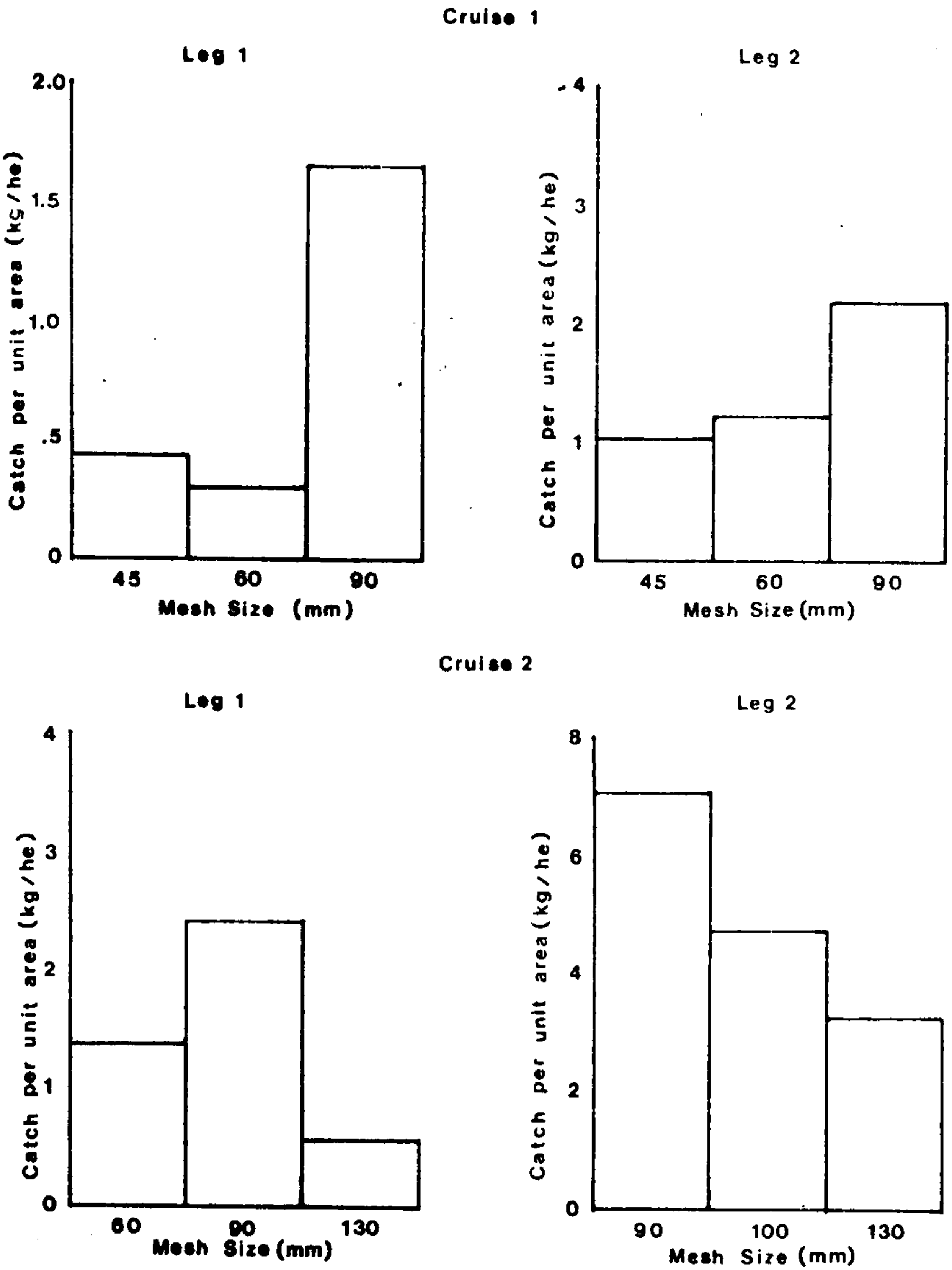


Figure 3. Histograms showing mean catch per unit area for each leg of Cruise 1 **and 2, stratified** by mesh size.

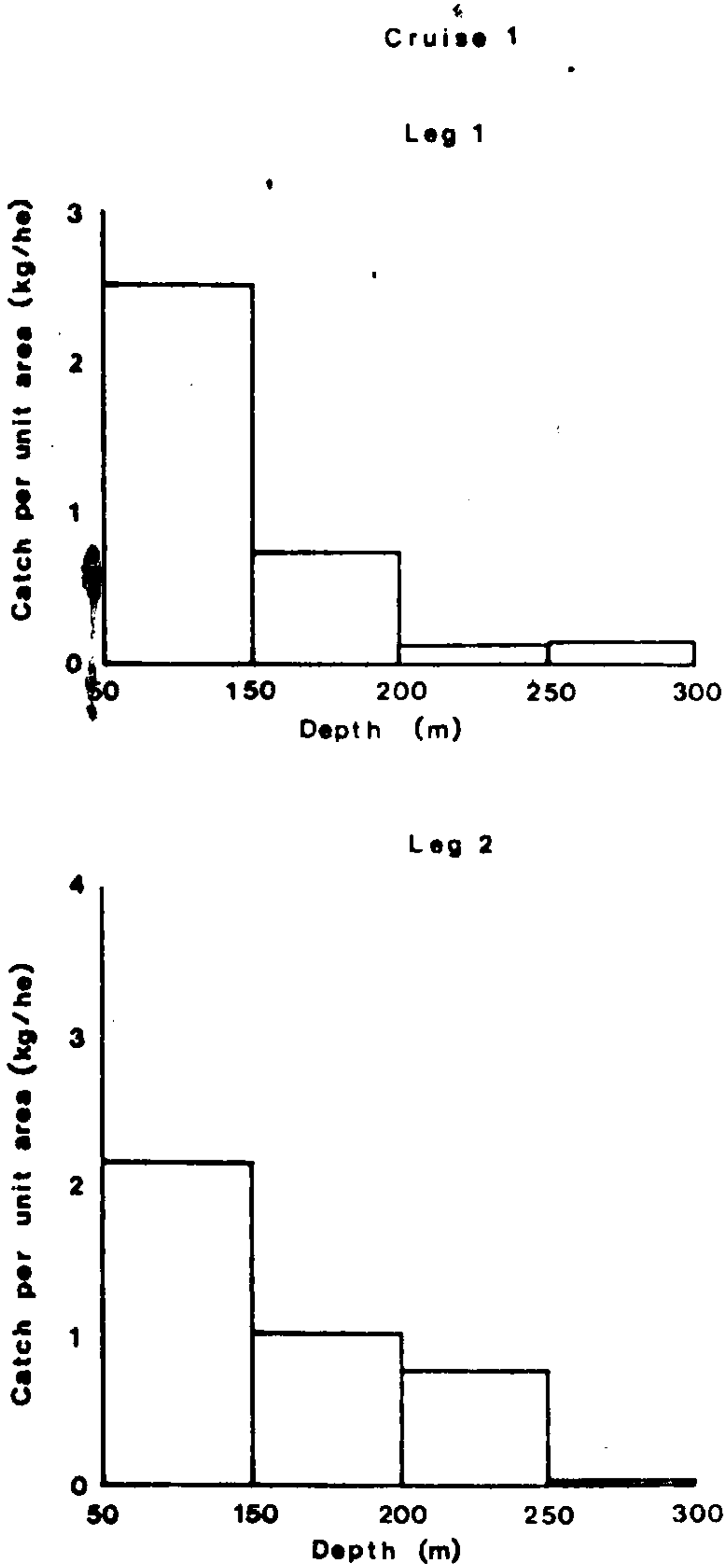


Figure 4a. Histograms showing mean catch per unit area for each leg of Cruise 1, **stratified by depth.**

Cruise 2

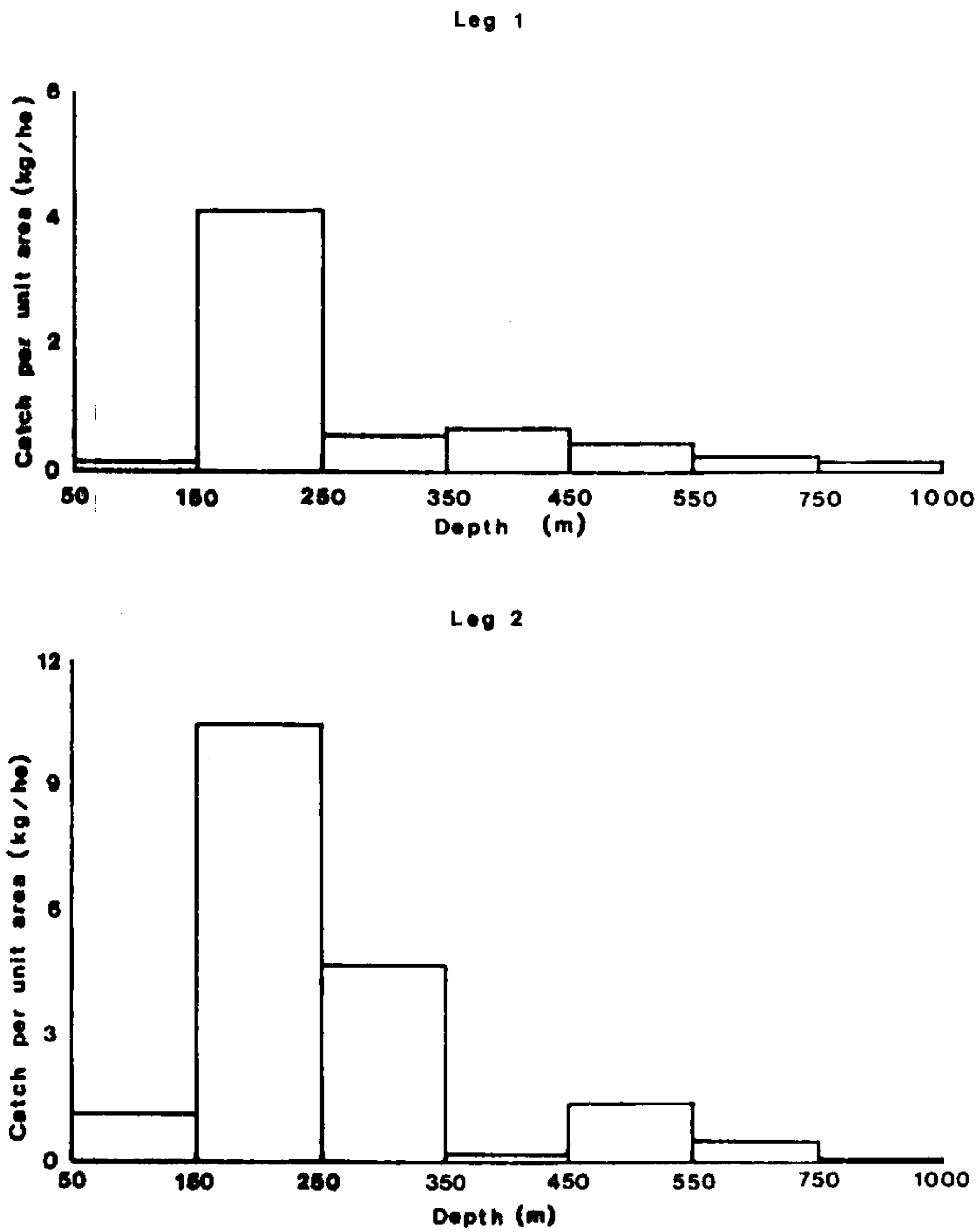


Figure 4b. Histograms showing mean catch per unit area for each leg of Cruise 2, **stratified by depth.**

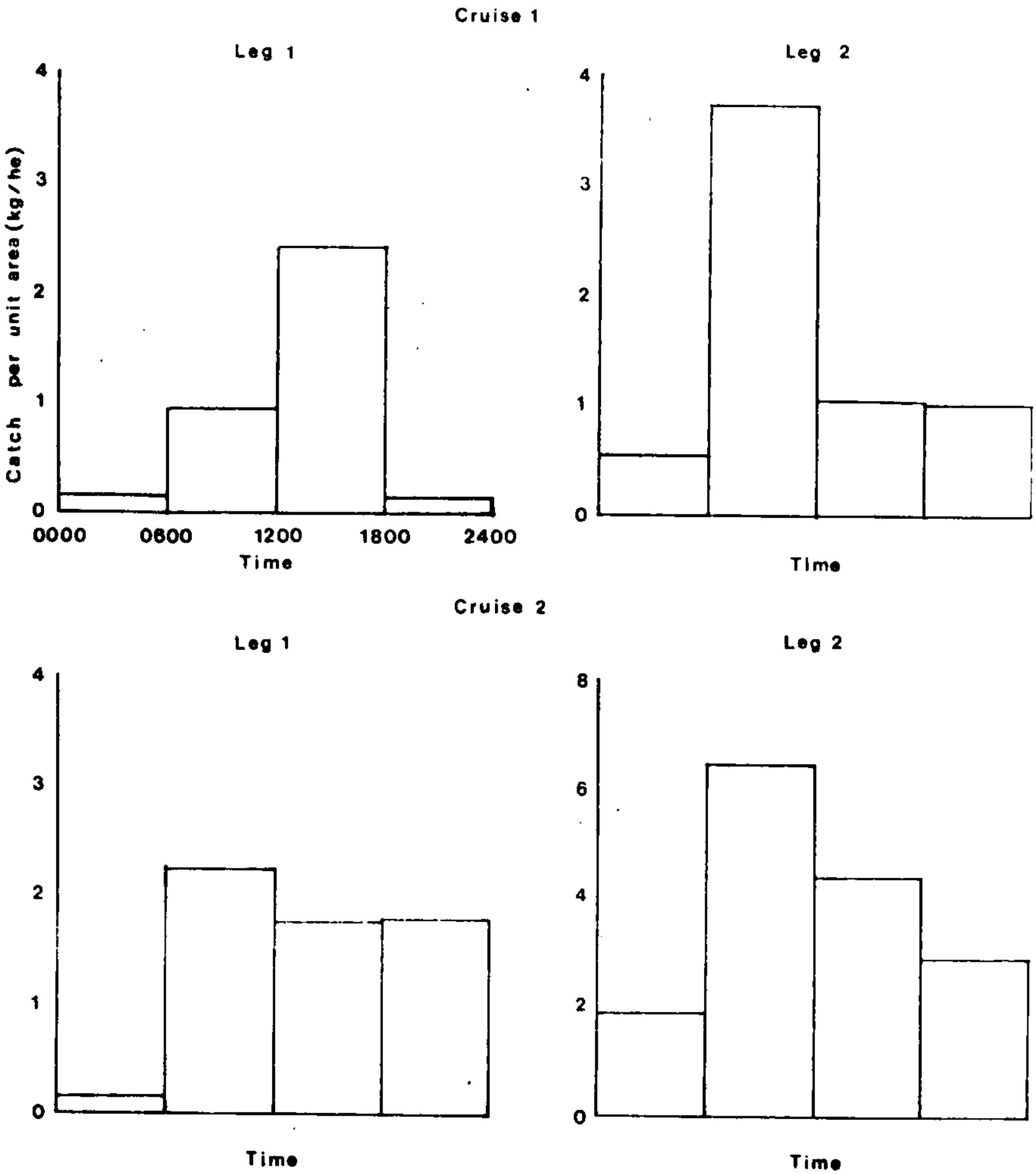


Figure 5. Histograms showing mean catch per unit area for each leg of Cruise 1 and 2, stratified by time.